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(54) A TEMPERATURE RESPONSIVE THROTTLING VALVE

(71) I, HENRY WILLIAM BURREINGTON, a British subject, of 6 Grenville Mews, Hampton Hill, Middlesex TW12 1BE, do hereby declare the invention (a communication from JACKES-EVANS MANUFACTURING COMPANY, a Corporation organized under the laws of the State of Delaware, United States of America, of 11737 Administration Drive, St. Louis, Missouri 63141, United States of America) do hereby declare the invention for which I pray that a patent may be granted to me and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an improved throttling valve, and more particularly to a throttle valve for throttling the flow of refrigerant leaving an evaporator of a refrigerating system so that ice is prevented from being formed on the surfaces of the fins of the evaporator during high humidity and low load demand conditions.

In refrigerating systems, such as automotive air conditioners, frost or ice formation on the surfaces of the fins of the evaporator results in inefficient operation as well as causes an annoyance to vehicle owners. Since an automotive air conditioner is exposed to all types of environmental conditions and is required to operate under various load demands at a wide range of engine speeds, it was common for the evaporator to become iced and frosted. This frosted condition normally occurs when the humidity is relatively high and when the load demand is decreased. Under these circumstances, the decrease in load causes the pressure of the evaporator to be sharply pulled down by the compressor. The drop in evaporator pressure is accompanied by a drop in temperature of the refrigerant which at approximately 32°F allows the moisture in the air to form frost and ice on the fins of the evaporator. If the build-up continues, the fins will eventually become completely clogged with ice so that no air will be able to pass through the evaporator and substantially no cooling will

result from the air conditions. In order to prevent such adverse conditions it is necessary to preclude a pressure drop in the evaporator during reduced load demand periods. It has been found that by measuring the temperature of the refrigerant flowing in the suction line, it is possible to prevent ice from forming on the evaporator by a throttling operation. That is, if a suitable temperature responsive throttle valve is placed in the suction line, throttling action is arranged to begin at approximately 39°F and continues so that no further drop in evaporator pressure and no further accompanying drop in temperature of the refrigerant can be caused by the lightly loaded compressor. Thus, the temperature of the evaporator can be maintained above the level at which the moisture of the air could form ice and frost on the surfaces of the fins.

Accordingly, it is an object of this invention to provide an improved temperature responsive throttle valve for regulating the flow of refrigerant from an evaporator in a refrigerating system in order to prevent the formation of ice on the evaporator. Another object is to provide such a throttle valve which is economical in cost, simple in construction, reliable in operation, durable in use and efficient in service.

In accordance with the present invention, there is provided a throttle valve in a refrigerating system for throttling the flow of refrigerant from an evaporator of the refrigerating system, the throttle valve comprising a valve body arranged to receive refrigerant from the evaporator and having an inlet and an outlet to allow flow of refrigerant therethrough, a power operating means mounted within said valve body, said power operating means including a container having a mass of temperature sensitive material therein which expands and contracts in accordance with the temperature of the refrigerant and the container being disposed directly in the path of flow of the refrigerant through the valve body so that the throttle valve responds immediately to

changes in temperature of the refrigerant, said power operating means further including a slidable member cooperatively associated with said container and arranged to be reciprocated relative thereto in accordance with the expansion and contraction of the said mass of temperature sensitive material, a valve member operated by said power operating means and arranged to be moved thereby away from and towards a valve seat in accordance with the reciprocation of said slidable member relative to said container, and a biasing spring acting to oppose movement of said valve member by said power operating means in response to expansion of said mass of temperature sensitive material, the arrangement being such that said valve member is normally spaced from said valve seat and is moved towards said valve seat during a decrease in temperature of the refrigerant so as to throttle the flow of refrigerant without completely terminating the flow at any time.

The invention will be more fully explained and better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

Fig. 1, partly schematic, shows one form in which the invention can be practiced.

Fig. 2 is a chart showing temperature-pressure conditions in a system using the Fig. 1 apparatus.

Fig. 3 is a temperature-motion diagram for a thermostatic power means usable in the Fig. 1 apparatus.

In viewing the drawings, and in particular Fig. 1, there is shown an automotive air conditioner system comprising a refrigerant compressor 10 driven from the engine through a suitable clutch (not shown), a refrigerant condenser 12, receiver 14, expansion valve 18 and evaporator 16. Valve 18 comprises a ported body 20 permanently assembled into the refrigerant system, and a removable valve cartridge 22 having a thermostatic actuator means 24. The actuator means 24 includes a sleeve 26 permanently affixed to the cartridge, as by the screwing at 28, a lower cap 29, a metallic diaphragm 30, and an upper cap 32, the various members being welded together by a continuous peripheral weld 34. The space between diaphragm 30 and cap 32 is occupied by a thermally expansible material 36, which might be the same material used in the refrigerant system or a suitable mix to provide special operating conditions for the purpose of ascending, descending or constant superheat characteristics, motor or system overload protection on both. Thermal insulation is provided at 37 to insulate the charge from the ambient temperature.

During operation of the system the refrigerant issues from the evaporator outlet

in gaseous form at a superheat determined by the adjustment of a spring 38 within the expansion valve. The superheat control occurs as a result of the opposing forces produced by thermal expansion of the charge 36 and spring 38 plus the pressure in chamber 42 acting on the diaphragm 30. Relatively high temperature gas in suction line 40 flows through chamber 42 in valve 18 and heats the body 20 and caps 29 and 32 as well as the pad 44 carried by diaphragm 30, thereby causing thermal charge 36 to produce a proportionate downward force on the valve stem 46. It will be appreciated that an upward force is exerted on the valve stem 46 when the temperature of the superheat decreases. Spring 38 develops an opposing upward force on the nut 47 and the stem 46, so that any movement of the metering valve element 48 is a function of the suction line temperature, all as conventional in the art. Variation in superheat setting can be achieved by turning nut 47 on the stem.

A throttling mechanism or throttle valve 50 is located in the suction line upstream from chamber 42. As shown, the valve includes a cylindrical metallic body or housing 52 having an inlet end internally threaded to receive the suction line 40. The outlet end of the valve body 52 is also internally threaded to receive an apertured plug or fitting 53 which is adapted to be threadedly screwed into the thermostatic expansion valve body 20. An O-ring 51 is located between the contiguous surfaces of the plug 53 and valve body 52 to prevent refrigerant from leaking thereby. The plug 53 includes an internally enlarged portion 54 and a tapered annular portion 55 which forms the valve seat, as will be described presently.

Located on the upstream side of valve seat 55 is a temperature-responsive power operating means 56 comprising a container 58, a piston 60, and a pellet-like mass of temperature-sensitive material 62 which expands upon transition from the solid state to the liquid state in response to temperature rise. Container 58 includes a cup-like element 64 and sleeve-like cover or tubular guide 66 suitably connected together for retention of an elastomeric diaphragm 68 and plug 70 in sealing relation to the pellet material 62. In operation, any temperature increase of the refrigerant vapor surrounding cup 64 causes the pellet 62 to transform from the solid state to the liquid state, thereby expanding to produce pressures on the diaphragm 68 sufficient to move plug 70 bodily outwardly relative to sleeve 66. The piston 60 is arranged to slide fit in the tubular guide 66 and is adapted to be reciprocated relative thereto in response to the expansion and contraction of the pellet 62. The free end of the piston is threaded

as shown at 71 and is screwed into the central aperture of a spider member 72. The free end 71 includes a slot which allows for calibration of the valve setting and after the necessary adjustments have been made a lock or retention nut 73 is screwed onto the threaded portion 71. The spider 72 is preferably cup-shaped and includes a number of radially extending legs, the outer extremities of which join with a substantially wider annular flange. The spider 72 is preferably stamped of sheet metal or the like and is press fitted into the enlarged portion 54 of plug 53. A relatively tight fit is ensured by the fact that a substantially large surface area is provided by the annular flange of the spider 72. A valve element or member 74 is screwed onto the threaded portion provided on the free end of tubular guide 66. The surface of the valve member 74 adjacent the plug 53 is also tapered to match tapered valve seat 55. A spiral compression spring 75 is disposed between the inner surface of the valve member 74 and the inner wall formed on the inlet end of the valve body 52. The compression spring 75 effectively surrounds the power operating means so that no additional space or length is required. The compression spring 75 is arranged to normally urge or bias the valve member 74 towards valve seat 55. Under normally operating conditions, the piston 60 is extended due to the liquified expanded pellet 62 so that the valve member 74 is moved away from the valve seat 55, as shown in Fig. 1. Now when the temperature of the refrigerant vapor surrounding cup 64 decreases the pellet 62 will begin to solidify and contract thereby allowing the compression spring 75 to depress the piston 60 into the container 58 so that valve member 74 moves towards the valve seat 55.

Pellet 62 preferably includes a mass of wax which undergoes solid-liquid transition in a temperature range near or spanning 32°F, as for example completely solid at 28°F and completely liquid at 39°F. Suitable waxes are commercially available for solid-liquid expansion in the desired range. Such waxes are mixtures of different hydrocarbons which produce the effective transition in wider or narrower temperature ranges according to composition of the pellet as determined by the initial fractionating and compounding, all according to known practice in the art. Fig. 3 illustrates the temperature-motion curve of a thermostatic power means useful in practice of the invention.

Pressures produced by pellet 62 expansion can be comparatively high, as for example over 2000 p.s.i., if the expansion process is resisted, as by holding the piston and container in their start positions. In the actual installation the pellet pressures may reach fairly high values since the piston and con-

tainer are restrained by the spring 75 and the radial friction loads between plug 70 and sleeve 66, plus the pressure difference across the valve due to the throttling action at 74. The capability of the pellet for producing relatively high forces is important in that it allows the temperature-responsive power means to move as a function of the suction line temperature without being affected by variations in suction line pressure. Suction line pressures are usually relatively low, on the order of 50 p.s.i. or less.

During operation of the illustrated system, the throttling element 74 will exert little, if any throttling effect as long as the suction gas temperature is above 39°F; valve member 74 is then spaced rightwardly away from seat 55, as shown. Should the temperature of the refrigerant in the suction line 40 drop below 39°F, valve member 74 will exert a progressively greater throttling effect according to how much the temperature drops, and at approximately 28°F, the member 74 will move towards seat 55, thereby reducing refrigerant flow from the evaporator to the compressor.

Compressor 10 is usually running on a continuous basis as long as the vehicle engine is running and the occupant has turned the air conditioner switch to the "on" position. On a continuous run basis for the compressor 10, the actual temperature in the passenger space can be controlled by dampers and/or variable speed fans operating on the air-stream flowing across the evaporator, or reheat from a suitable source, e.g., engine cooling water, condenser cooling water, heat rejected into condenser cooling air or any other convenient means. Assuming sufficient demand for air cooling, the evaporator 16 will be at a high enough temperature to prevent any icing on its fin surfaces. However, during low demand periods less refrigerant will be evaporated in the evaporator, and the continuously-running compressor will tend to reduce the pressure and temperature in the suction line and evaporator, all in accordance with curve 76 of Fig. 2.

If the throttling valve mechanism 50 were not in the system the evaporator temperature could well drop below 32°F so that ice and frost would tend to form on the fin surfaces. The drop in temperature is due to the fact that the compressor 10 would keep pulling down the pressure of the evaporator 16 so that a resulting drop in temperature would occur. However, in actual practice ice at 32°F is rather slushy or only temporarily on the fin surfaces due to air heating effects or air movement effects. Usually the fin temperature must get down to about 28°F before permanent ice and frost formations occur; 28°F is therefore chosen as the temperature at which throttling mechanism

50 reduces the flow of refrigerant from the evaporator to the compressor.

In operation of the system with mechanism 50 installed therein, the system functions in the normal manner at evaporator temperatures above 39°F. However, should the air-cooling demand or load be so reduced as to permit the compressor to lower the evaporator pressure below about 27 p.s.i. the corresponding drop in suction line temperature will cause material 62 to partially solidify so as to produce a throttling action by movement of valve element 74 towards seat 55. The throttling action will cause several things to happen, as follows: first, the pressure in the evaporator will be higher than if no throttling had taken place, and second, the superheat in chamber 42 will be somewhat higher than otherwise when chamber 36 is system charged. Thus, the throttling valve mechanism 50 prevents the compressor 16 from reducing the temperature of the evaporator 10 to a level which would cause ice and frost to form on the surfaces of the fins of the evaporator.

The throttling mechanism 50 may be located on either side of chamber 42 and may be situated in any convenient location in the suction line, evaporator housing, or compressor manifold. It is preferred to wholly or partially isolate the thermal charge 36 from the evaporator temperatures during the throttling periods. This isolation effect is advantageous in that charge 36, depending upon its composition, may assume an artificially high temperature for more fully opening the metering element 48. In addition, the pressure drop across seat 55 caused by the throttling of valve 50 reduces the pressure in chamber 42 exerted upwardly on pad 44 and diaphragm 30 which allows the metering element 48 to more fully open. This action tends to produce a flooding action in the evaporator, both because element 48 is feeding the evaporator with liquid and because element 74 is restricting the escape of gas from the evaporator. Such flooding tendency raises the evaporator pressure and evaporator temperature, thus producing a de-icing and/or icer-prevent action on the evaporator surfaces. The temperature-pressure relationship will follow line 78 rather than the normal curve 76 as shown in Fig. 2.

It will be understood that the operation is a modulating action wherein throttling and pressure-temperature changes may be gradual without full closing or full opening of element 74, preventing compressor starvation and eliminating the necessity of cycling the compressor. Also, the described temperature of 28°F normal full-throttle and 39°F normal full-open are somewhat arbitrary; useful results may be achieved using different temperature ranges. In general, however, it is pre-

ferred to choose temperatures which are just above the evaporator fin icing level this lets the evaporator have more cooling capacity with a given surface area, thereby permitting a smaller evaporator for a given duty.

It is of some importance that power operating means 56 be insensitive to pressure variations in the suction line, and that power operating means 56 have sufficient force capability to open and close the throttling element 74 independent of the pressure drop across seat 55. If a low force power means such as a bimetal or liquid-charged bellows were used in lieu of power means 56 the pressure drop across the valve seat would tend to increase the throttling effect to an undesirable extent, sufficient to prevent normal operation of the system. Therefore, the thermostatic power means must be pressure-insensitive for proper results.

The drawings show power operating means 56 as a wax-charged element wherein temperature decrease produces contraction of pellet 62. It is contemplated that the charge could be water instead of wax, in which case a temperature decrease to a value below approximately 32°F would produce a change of state from liquid (water) to solid (ice) with an accompanying expansion of the charge. In this case the relationship between the valve element 74 and seat 55 would be such as to produce throttling on expansion of the charge.

An advantage is realized by disposing the compression spring 75 between the valve member 74 and the inner wall of the inlet side of the valve body. It will be noted that a separate space is not required for the spring 75 since it effectively surrounds the power operating means 56, and therefore, the length of the valve body 52 may be effectively shortened. Such a space saving feature is very desirable, particularly in an automotive application where space is at a premium.

On hot days, the temperature under the hood of a motor vehicle may be 175°F or above which can cause the piston 60 to be extended beyond its normal length of travel. This over-travel does not adversely affect the arrangement as shown in Fig. 1 since the spring 75 will allow further movement of the power operating means 56 so that no damage will occur to the valve parts during periods of overheating.

It has also been found highly advantageous to place the container 64 adjacent to the inlet side of the valve mechanism rather than adjacent its outlet side. Further, with the disposition shown, the container is exposed to the suction line from the evaporator which is the condition to be sensed by the temperature sensitive material 62. Thus, more effective results and quicker response to changing evaporator conditions will be pro-

duced with the power operating means disposed as shown.

The throttle valve mechanism 50 can be used with conventional and typical thermostatic expansion valves, in addition to valve 18 described herein, and/or other types of refrigerant liquid expansion flow control means such as capillary tubes for purposes of evaporator temperature regulation.

An additional benefit of utilizing the throttle valve mechanism 50 is that the compressor 10 is not required to work as hard as compressors in previous refrigerating systems in that the head or discharge pressure of the compressor is reduced in proportion to the amount of throttling action.

This throttle valve mechanism 50, like previous valves having closely fitting sliding members, is insensitive to small dirt particles thereby providing long and dependable life expectancy.

It will be appreciated that while this invention finds particular utility in automotive air conditioner systems, it is readily evident that the invention is not limited thereto, but may be employed in other refrigerating systems and in other environmental settings.

WHAT I CLAIM IS:—

1. A throttle valve in a refrigerating system for throttling the flow of refrigerant from an evaporator of the refrigerating system, the throttle valve comprising a valve body arranged to receive refrigerant from the evaporator and having an inlet and an outlet to allow flow of refrigerant therethrough, a power operating means mounted within the said valve body, said power operating means including a container having a mass of temperature sensitive material therein which expands and contracts in accordance with the temperature of the refrigerant and the container being disposed directly in the path of flow of the refrigerant through the valve body so that the throttle valve responds immediately to changes in temperature of the refrigerant, said power operating means further including a slidable member co-operatively associated with said container and arranged to be reciprocated relative thereto in accordance with the expansion and contraction of the said mass of temperature sensitive material, a valve member operated by said power operating means and arranged to be moved thereby away from and towards a valve seat in accordance with the reciprocation of said slidable member relative to said container, and a biasing spring acting to oppose movement of said valve member by said power operating means in response to

expansion of said mass of temperature sensitive material, the arrangement being such that said valve member is normally spaced from said valve seat and is moved towards said valve seat during a decrease in temperature of the refrigerant so as to throttle the flow of refrigerant without completely terminating the flow at any time.

2. A throttle valve as claimed in claim 1, wherein said container is disposed adjacent said inlet and said valve member is disposed adjacent said outlet.

3. A throttle valve as claimed in claim 1 or 2, wherein said biasing spring is situated between said valve member and a wall formed near said inlet and surrounds said power operating means.

4. A throttle valve as claimed in claim 1, 2 or 3, wherein said slidable member is a piston having its free end connected to a spider member which is press-fitted into the outlet of said valve body.

5. A throttle valve as claimed in claim 1, 2, 3 or 4, wherein said valve member is securely fixed to said container of said power operating means.

6. A throttle valve as claimed in claim 4, wherein said free end of said piston is adjustably connected to said spider member.

7. A throttle valve as claimed in claim 1, wherein said valve body is a cylindrical metallic structure which is adapted to be coupled with a conduit line carrying the fluid.

8. A throttle valve as claimed in any one of the preceding claims, wherein said mass of temperature sensitive material is a wax which undergoes a solid-liquid transition in accordance with the temperature of the fluid.

9. A throttle valve as claimed in any one of the preceding claims, wherein the said valve body is a cylindrical member having said inlet formed in one end and an apertured plug threadedly screwed in the other end forming said outlet.

10. A throttle valve as claimed in claim 9, wherein said valve seat is formed on the inner surface of said apertured plug.

11. A throttle valve as claimed in claim 1 substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

For the Applicant:
BERNIER & BURRINGTON,
Chartered Patent Agents,
6 Grenville Mews,
Hampton Hill,
Middlesex TW12 1BE.

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the Original on a reduced scale

